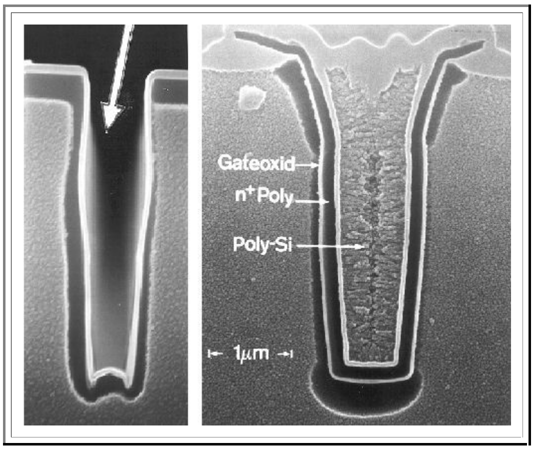
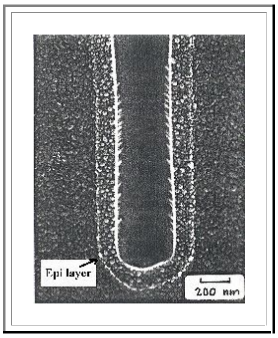
Doping Trench Walls

- You have a trench (i.e. in reality a hole) with a diameter of about **1 µm** and a depth of **5 µm**. The **Si** around it serves as one of the capacitor electrodes and must be doped with something to a depth of about **0,3 µm** so it is highly conductive.
  - This task came up as an unprecedented challenge to process engineers in the context of the **4 Mbit DRAM** generation around **1985**. How do you do it?
- First you try what you have - ion implantation - and hope for the best. Since the ion beam does not impinge at right angels on the specimen, but somewhat off (say about 10^{o}) for various reasons, there is hope.
  - Indeed, it works - see below:



- With a special etchant the doped region is etched off, leaving a dark rim around the trench (which was not very perfectly etched at this point in time).
  - The arrow in the left-hand picture marks the major direction of the ion beam, and the left-hand side of the trench is nicely doped, as one would expect. The right hand picture shows a fully processed trench capacitor for measurements of the electrical characteristics.
  - But some implantation also took place on the unfavorable side - there is a certain spread in the beam angle, some ions are reflected or scattered off their original direction - whatever happens, some ions hit the wall. If you turn the wafer during implantation, it might be possible after all, to obtain decent homogeneous doping.
  - But in the end, ion implantation was not used. Too expensive, too dependent on the precise trench geometry (which changes all the time), simply not good enough for prolonged mass production.
- OK, so you try epitaxy. Simply deposit the doped layer into the trench as you want to have it.
  - Allright - it works. Some problems are encounteres around the opening of the trench, but nothing that couldn't be solved eventually. The picture shows part of a trench with the doped epi layer; this looks good.



  - But we don't use it for production! The reason is simple: Too expensive, too hot - and we can do it better in a different way.
- How? Well, let's deposit a "**spin-on glass**" (***SOG***)containing the dopant, hope that it will completely fill the trenches, and then diffuse the dopant out of the **SOG** into the **Si**.
  - Spin-on glasses are used a lot, but do they fill up fine holes? The only way to find out is trying it.
  - To cut a long story short - it worked. But not reliably enough; didn't make it to production.
- What finally made it to production is a somewhat similar approach, except that the **SOG** was replaced by an **A**s doped **TEOS**-oxide.
  - Not an extremely nice process (the coating of the **CVD** tube is **As** contaminated and highly toxic), but without many unknowns and reproducibly.
- Is there something even better?

- Yes, there is a simple solution to the trench doping problem: *Don't do it*. Oxidize the trench walls and deposit a layer of highly doped poly-**Si** as the capacitor electrode. Simple. Elegant.
- Except that now you have to produce the very thin capacitor dielectric on poly-**Si**. Thermal oxidation of poly-**Si** will not be good enough - now you need **ONO**. The result was already shown in an illustration module